National Aeronautics and Space Administration

IAPG Spring Steering Group Meeting
Strategic Analysis Executive Conf. Center; Arlington, VA
April 10-11, 2013

NASA Agency Update

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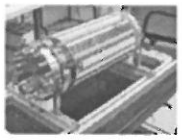
Alternate Steering Group Representative

National Aeronautics and Space Administration

Recent Accomplishments in Electrochemistry



Significant Accomplishment:
The 3kW non-flow-through **fuel cell stack** has been assembled, delivered to GRC and is undergoing acceptance testing and the performance check. Most of the balance-of-plant hardware has been procured and integration is expected to being in early April.

NFT Fuel Cell Stack

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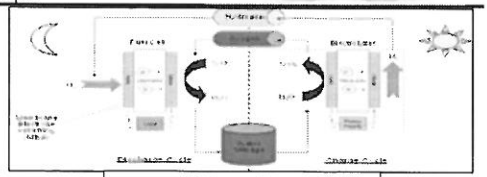
SF Electrolyzer Stack



RFC Concept Diagram

Significant Accomplishment:
A media event was held January 22 in downtown Cleveland in front of the Greater Cleveland Regional Transit Authority to show off a new hydrogen-powered bus served by Ohio's first operational **electrolysis-based refueling station**.

Refueling station

route for fuel-cell powered bus: Downtown Cleveland

Significant Accomplishment:
AMPS program targeting design, build, testing and delivery of two 120 Volt Lithium Ion Modular Batteries - identified candidate cell chemistry and capacity; defined Battery requirements, architecture, and desired features

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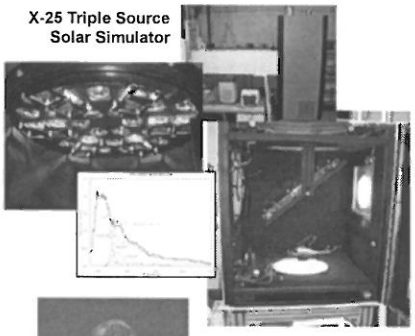
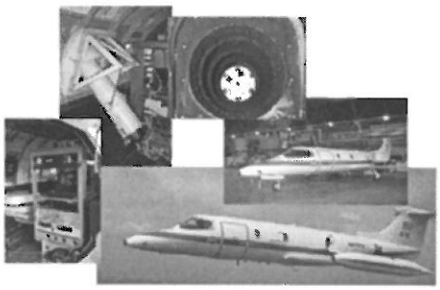
Photovoltaic and Power Technologies Branch (RPV)

Generation of Air Mass Zero (AM0)/Space Calibrated Solar Cell Primary Standards In Support of PV Laboratory Measurements

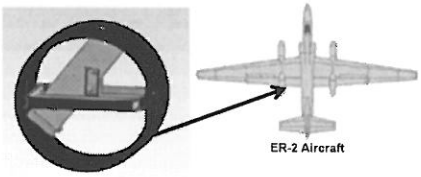
X-25 Triple Source Solar Simulator





NASA GRC Lear Jet 25 and NASA Dryden Aircraft Operations Facility ER-2

Near Space Calibration of Advanced Photovoltaics (NSCAP) High Altitude Balloon



ER-2 Aircraft

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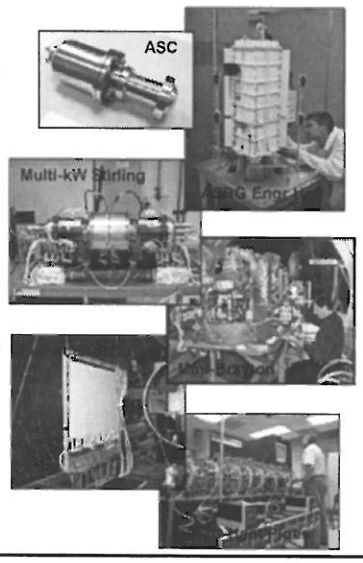
Thermal Energy Conversion Branch (RPT) Overview

Description

- Provide world-class thermal energy conversion technology to support future space missions
- Mature technologies through concept design, analysis, component development and testing
- Demonstrate system-level technology readiness
- Serve as the agency's leader for space radioisotope and fission power system technology development
- Work collaboratively with the DOE, industry, and academia

Focus Areas

- Stirling, Brayton, Rankine, and thermoelectric energy conversion
- Radioisotope and fission reactor heat source integration
- Advanced radiators, heat exchangers, and thermal control
- Advanced alternators, electrical controllers, and permanent magnets
- Component and end-to-end system performance testing
- Life and reliability verification
- Analytical tool development, system modeling, and conceptual design



Facilities & Labs

- Stirling Research Lab
  - Approx. 12 Ambient Test Stations
  - 24/7 Endurance Testing
  - Small Space Env. Thermal-Vac (VF67)
  - NPR 7120.8 compliant QMS
- Advanced Engine Concepts Lab
  - Thermoacoustic and Alpha-STREAM Stirling technologies
- Heat Rejection Lab
  - Ti/H2O Heat Pipes
  - Sub-scale Composite Radiators
  - Small Lunar Env. Thermal-Vac (VF17)
- Large Thermal-Vac Facility (VF6)
  - 24 m long x 8 m dia. w/LN2 & Solar Sim.
  - Large Radiator & Integ. System Testing

Accomplishments

- >60 years cumulative life testing on RPS-class Stirling convertors
- Advanced Stirling Convertor (ASC) technology transition to flight
- Advanced Stirling Radioisotope Generator (ASRG) Engineering Unit
- Multi-kilowatt Stirling and Brayton performance demonstration tests
- 100-200°C Ti/H2O heat pipe R&D
- Full-scale composite Radiator Demonstration Unit (RDU) test
- Fission Technology Demonstration Unit (TDU) design and development

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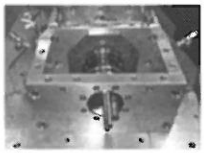
Thermal Energy Conversion Branch Recent Accomplishments

ASRG Engr Unit Extended Operation Testing Exceeds 30,000 Hrs

Single-ASC Small RPS Tested with APL Controller

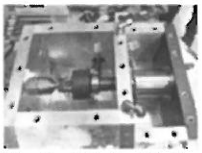
Ti-H2O Heat Pipe Radiator Tested in Thermal-Vac

TDU Subsystem Development & Testing Nearly Complete



ASC Durability Testing Demonstrates Launch Survival

VCHP Heat Shunt Demonstrated with Stirling Convertor



Structural Testing Verifies Heater Head Integrity

Final Engr Model ASC-E3s Delivered to GRC for Testing

Ti-H2O Heat Pipe Flooding Limits Evaluated in Microgravity

Nuclear-heated Stirling Test Completed at Nevada Test Site

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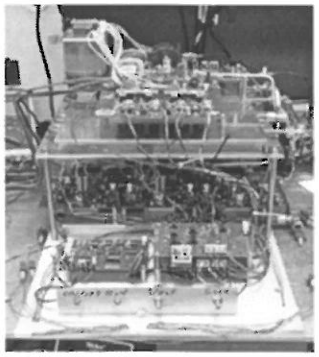
HP-300V Power Processing Unit (PPU)

Objective

- Develop a brass board power processor that incorporates high voltage Silicon Carbide (SiC) switching devices in support of a 15kW, high efficiency, Hall Effect electric propulsion Thruster (HET)
- Development effort includes:
  - CREE SiC MOSFETS
  - Medium fidelity Packaged Brassboard
  - Thermal Design
  - Operation in vacuum
  - Electric Circuit and Thermal Models
- The SiC PPU:
  - 15kW total power
  - An input voltage from 250V to 330Vdc,
  - Input current of 50A at full power
  - Peak Overall Efficiencies ≥ 96%
  - Output Voltage adjustable from 500V to 200Vdc @ 50Adc
- Brass board consists of:
  - Discharge supply contains two 7.5kW modular power units
  - Heater/Keeper/Magnet Supplies
  - Master Control
  - System Controller
  - Input Filters



15 kW Breadboard Discharge Supply

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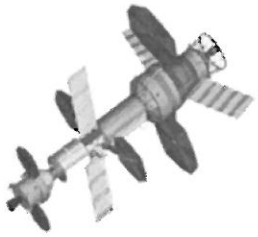
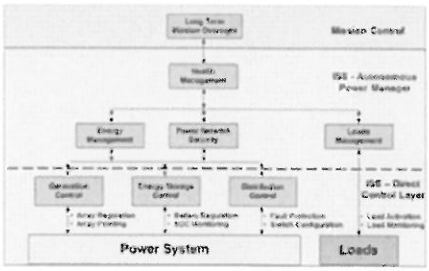
Power Controls and Automation

Objectives

- Long Term operation of remote assets with minimal human intervention -- operational autonomy
- Address issues of communication time lag
- Rapid fault detection and reconfiguration of the power network
- Management of generation and storage
- Load management under variable load demand & constrained capacity
- Failure diagnostics and prognostics for power components





Approach

- High fidelity modeling and simulation
- Multi-layer hierarchical control using Agent based systems

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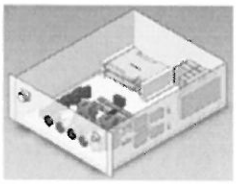
Advanced Modular Power Systems (AMPS)

Objective

- Create a set of power modules that can be scaled and used for multiple applications

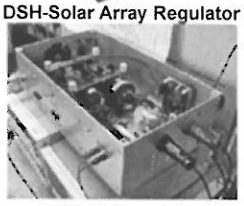
Objective for FY13

- Design, develop and test, and deliver to the JSC-Deep Space Habitat (DSH) program
  - A 6kW Modular Solar Array Regulator
  - Breadboard Power Distribution Unit (PDU)
    - 8 Four-amp channels that can be paralleled
- Develop a modular bi-directional converter for Lithium-ion Batteries.
  - 8V to 120V converter for 2-cell battery module
- Major accomplishment so far in FY13
  - Completed design of the solar regulator design and PDU
  - Completed design and development of a 2-cell battery/bidirectional converter module



BB Modular PDU

DSH-Solar Array Regulator



2-Cell Battery Module